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AUTONOMOUS SURFACE CLEANING ROBOT BLUETOOTH CONTROLLED

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ABSTRACT
Automation of cleaning technology has come a long way, with smart solutions for household and commercial use. This paper describes an autonomous robot for surface cleaning that performs mopping and dusting tasks with high efficiency. The equipment is Bluetooth-operated, with voice and remote command. A new edge-cleaning system is engaged by obstacle detection, providing better cleaning capability. A metal detection system also ensures internal protection by warning users of dangerous items. The real-time alert system of the robot enhances user vigilance and process control. Experimental results show enhanced navigation, adaptability, and performance optimization in different environments.

Keyword
Autonomous Robot, Cleaning, Arduino, Obstacle Detection, Bluetooth Control, Voice Control, Metal Detection.

1. INTRODUCTION

With the growing need for domestic and commercial cleaning automation, the development of autonomously controlled cleaning robots is a matter of greater significance. The traditional cleaning methods are based on manual work, so they are time-consuming and labor-intensive. Robotic vacuum cleaners and floor scrubbers have recently been introduced [1]-[6], but they tend to be limited with adaptability, precision, and the ability to operate in difficult environments. Most cleaning robots available in the market are constrained by their weak navigation capabilities for obstacles, inability to sense harmful material, or inability to pass through difficult-to-clean areas[3]. Moreover, traditional designs lack the feature of possessing an advanced mechanism to sense and eliminate sharp objects, which can pose safety risks to users and the robot.

To counter these issues, our proposed cleaning robot utilizes a number of cutting-edge technologies to enhance cleaning efficiency, user convenience, and safety. The robot features a Bluetooth-based remote-control system, allowing users to easily control it using a mobile application or voice commands. This provides easier access, especially for mobility-impaired individuals. An ultrasonic sensor is used for obstacle detection to allow the robot to move effectively without colliding with objects. There is also a metal detecting alert system which sends the alert notification to registered mobile number when the metal is detected

With the addition of remote-control operation, real-time obstacle detection, and a groundbreaking hazardous object removal system, this cleaning robot offers a more comprehensive solution than is available today. The system aims to reduce the amount of human intervention in cleaning tasks and increase performance in dirty and complicated settings. Unlike conventional designs that only resort to suction power or mechanical scrubbing, our design prioritizes effectiveness and safety. Thus, it is the ideal solution for home, office, and industrial settings where cleanliness is to be maintained with ease.

2. OBJECTIVES

The main goal of this project is to develop a cost-effective and effective cleaning robot that solves most of the problems in robot cleaning. Most of the current cleaning robots are inflexible, have no object navigation

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ability[4], and give no real-time warnings for potential damage[1]-[6]. Our system solves these problems by incorporating necessary technologies that improve its functionality and usability. We aim to design a cleaning solution that is affordable and dependable, allowing automation to reach more people.
One of the most significant features of this cleaning robot is that it has an object detection system using ultrasonic sensors. The system ensures real-time detection of objects in its path, thus enabling effortless navigation and preventing possible collisions. Additionally, the robot features Bluetooth-based remote control, enabling users to control it manually when necessary. This feature ensures more control from the users, thus enabling the system to adjust to various cleaning environments, ranging from homes and offices to industrial settings.
Safety is also an essential component of the project, addressed by incorporating a metal detection warning system. On detecting metallic materials, the robot automatically alerts a registered phone number, hence enabling users to take appropriate precautions. The functionality is particularly valuable in environments where metallic debris can pose safety hazards. Further, for efficient cleaning performance, the robot is also designed with a water pump and mopping system, thereby enhancing its effectiveness in dirt and stain removal. Through such innovations, the project seeks to enhance cleaning automation while concurrently enhancing safety, convenience, and efficiency.

3. RELATED WORK

[1] Gargi Ashtaputre and Amol Bhoi have proposed an AI- based robot cleaner, which removes most of the dirt-related loss of efficiency from the panels. Even though it supports a dust analysis algorithm with an HMI interface so that remote control operation can take place, its specialty acts as a restraint from cleaning weirdly shaped household corners, which often require harder accesses. Further, no provision of voice control makes users unable to reach their maximum convenience from such an exhaustive cleaning robot.
Bhumika T J et al. have discussed the limitation of the present cleaning system in which infrared sensors fail to detect dark objects and also suffer from light interference. They proposed ultrasonic sensors for higher accuracy in detecting objects and voice recognition for better interaction with the user
[2]. One disadvantage of this device is that there is no alert system, such as a buzzer, which will give one real-time feedback during its operations. It relies mostly on sensor technology, sometimes inadequate for complex environments. This may reduce navigation and cleaning efficiency.
This is about the co-creation opportunities for values of autonomous cleaning robots within services of cleaning, under stakeholder relations and the assumed benefits such as efficiency or technological branding
[3]. However, obstacles related to high development costs, the risk of vandalism, and the complexity to incorporate an autonomous system make it difficult.
[4] Thanushree V M et al described a compact and efficient robotic cleaner developed which uses a scrubber attached to a motor to perform efficient cleaning with a further scope for optimization. It is promising for the future of revolutionizing the cleaning industry, but its drawbacks include the potential loss of energy from the motor, and improvement in efficiency and durability of the scrubber, especially about small plastic fibers.
This shows a good basis for future developments with multi-tasking capabilities, such as trash selection and water quality monitoring, using a robust design with two pontoons to ensure stability and a payload capacity of 20 kg[5]. However, the disadvantages are that it requires more research on interfacing between modules and ensuring static balance, especially when the waste container varies in load, which may affect the robot's operational stability in water.
An autonomous cleaning robot for floor surfaces shows a great possibility in improving cleaning efficiency and addressing issues like debris accumulation and obstacle avoidance. In this project, intelligent algorithms are implemented, along with features for remote operation, making the system effective in navigation and execution of tasks. The challenges that remain include adaptation in numerous cleaning environments and continuous optimization in effectiveness, which may challenge the performance of the robot in complex spaces[6].

4. PROPOSED APPROACH

The suggested cleaning robot aims to further automate the process of cleaning using the integration of Bluetooth remote control, ultrasonic sensor-based collision detection, and a metal detection warning system. In contrast to AI-based cleaning robots through SLAM-based algorithms, this system is pre-programmed with control mechanisms and sensor inputs. The robot provides smooth movement, real-time threat alerts, and

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efficient cleaning operations.
The robot is driven by four wheel motors with the help of an H-Bridge motor driver IC. The robot is controlled by sending commands through an HC-05 Bluetooth IC, allowing remote control through a mobile application. The functions used to move the robot are:

Forward (F): Move the robot forward.
Backward (B): Move the robot backward.
Start (S): Start the cleaning process.
Stop (D): Stop all operations.
Left (L): Make the robot turn left.
Right (R): Make the robot turn right.
Pump On (PO): To activate the water pump so that the robot can perform mopping.
Pump Off (PF): Used to deactivate the water pump.

To sense obstacles, an HC-SR04 ultrasonic sensor is used to measure the distance by sending ultrasonic waves and measuring the time taken by the echo to return. When an obstacle is detected within a given range, the robot stops and moves in the other direction to avoid collision. A buzzer is triggered to notify users of the obstacle detection. And when the robot reaches the obstacle the pump turns on and cleans ensuring complete edge cleaning.
The cleaner mechanism uses a water pump that sprays water on the surface, and a mop on the base ensures that the surface is cleaned. The pump is controlled by a relay module, which switches the water flow on and off when needed. One of the special features of this system is the metal detection alarm system, contributing to safety by identifying metallic objects on the floor. A metal detecting sensor continues to scan the area to be cleaned; in case of metal detection, the robot provides a warning buzzer and sends a message "METAL DETECTED!" to the mobile number, the process taken care by the GSM (Global Systems for Mobile Communications) module . This feature enables fast detection of sharp or dangerous metallic objects, thus preventing possible harm.

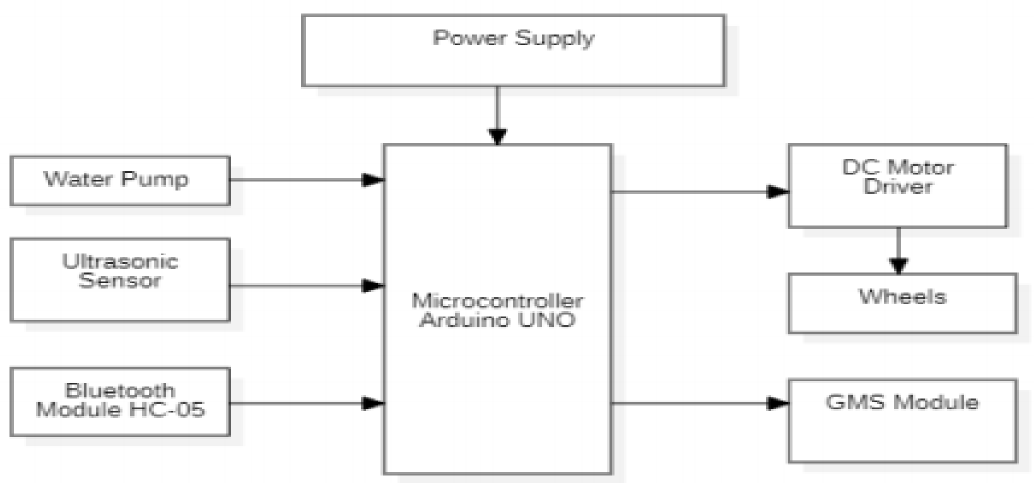

Fig 4.1 : System Architecture

The whole system is fueled by lithium-ion batteries that give it portability and continuous use. The robot operates on a rule-based system, hence becoming an economic and effective solution for domestic and business cleaning needs.

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SI NO.	NAME OF THE COMPONENT	QUANTITY
1.	Arduino Uno Boards	2
2.	Metal Detector	1
3.	GSM Module and Bluetooth Module	1
4.	Water Pump and 9v battery	1
5.	Relay Module and DC Motor Controller	1
6.	DC Motor	2
7.	Lithium Ion Batteries	3
8.	Wheels	4
9.	Jumper Wires	required

Table 1- Components Required

5. ALGORITHMS USED

1. **Reactive Control Algorithm** – the robot responds to present sensor input (i.e., when it sees an obstacle, it stops, turns left, and continues). It does not map or remember locations.
2. **Rule-Based Decision Making** uses if-else conditions to decide the movements of a robot, depending on sensor readings and Bluetooth inputs.
3. **Simple Obstacle Avoidance** – Deploys an ultrasonic sensor to sense objects and turn around but does not have SLAM or path planning for optimal navigation.
4. **Finite State Machine (FSM)** – The robot is in pre-defined states: Move, Stop, Turn, Detect Metal, and Activate Pump. Each state changes according to some conditions.
5. **Bluetooth Communication Algorithm** – Implements remote control commands from a smart phone via an HC-05 module for movement and cleaning tasks.
6. **The Metal Detection Alert Algorithm** is designed to detect metallic objects and subsequently send an alert message to a registered mobile number via the GSM module.
7. **Motor Control Algorithm** – Controls the movement functions (forward, back, left, right, stop) based on Bluetooth and sensing inputs.
8. **The Cleaning Mechanism Algorithm** starts the mopping mechanism and water pump whenever it receives a command or after obstacle removal.

6. RESULT ANALYSIS

The cleaning robot was successfully tested to gauge its capability to conduct simple cleaning functions with the incorporation of obstacle detection, remote operation through Bluetooth control, and metal detection warning. The movement functions—i.e., forward, backward, left, right, and stop—were responsive to commands sent through the Bluetooth module. The robot was able to move efficiently on various floor surfaces with stability and precision of movement.

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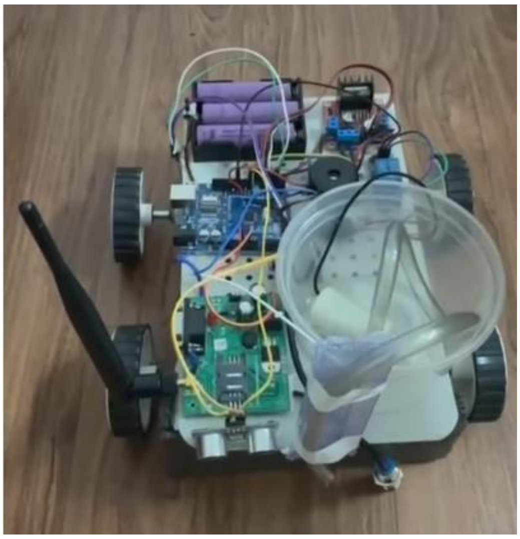

Fig 5.1: Top view of Robot

The ultrasonic sensor obstacle detection system worked well to detect obstacles on the path of the robot. When an object was detected within the given range, the robot halted and altered its direction to steer clear of the collision and cleaned the area. The operation of the buzzer as an activation signal provided an audible signal verifying the detection of an obstacle. The sensor response time was steady, providing real-time robot path adjustment.

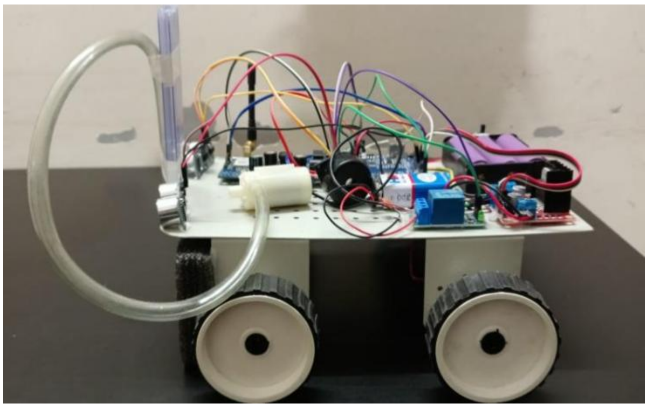

Fig 5.2: Front view of Robot

The metal detector system worked as intended, effectively detecting metallic objects on the ground and triggering an alert system. Upon detection of metallic objects, the buzzer was activated, and the GSM module sent an alert message "METAL DETECTED!" to the registered phone number.
The reliability of the metal detecting process was ensured through the testing of different metallic objects, thus confirming the effectiveness of the system. The mopping system and water pump also worked effectively, thus confirming the cleaning process.
Overall, the results confirmed that the robot serves its purpose, providing an automated, remote-controlled, and safety-improved cleaning solution.

7. CONCLUSION

Development of this floor robot clearly demonstrates a new practical and affordable solution for autonomous floor cleaning. With the integration of Bluetooth-based remote control, ultrasonic sensor-based collision avoidance, and metal detection alert features, the robot adds considerably to functionality and safety. The

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system travels effectively through various environments and navigates around obstacles in real time while continuing thorough cleaning with its water pump and mopping system.

The incorporation of a metal detection system provides an essential safety feature by alerting users of the presence of sharp or dangerous metal objects, thus preventing accidents. The incorporation of Bluetooth connectivity allows easy remote control, thus making the robot suitable for domestic and commercial use. Additionally, the modularity of the robot offers scalability, which can accommodate future upgrades, such as higher automation and better cleaning efficiency.

In general, this project is able to fulfill its function and provide a viable solution for automated cleaning systems. With advancements in power efficiency and sensor technology in the future, the system can be optimized to perform even better. This study highlights the capability of smart cleaning robots to minimize labor and maximize hygiene levels in different settings.

8. FUTURE ENHANCEMENTS

To transform the cleaning robot into a completely autonomous and intelligent system, various advanced technologies will be combined. One of the major upgrades is the replacement of the existing ultrasonic sensor with a LiDAR-based system to facilitate accurate obstacle detection, high-resolution spatial awareness, and thorough coverage of the cleaning space, including tight edges and corners. This will be supplemented by AI-driven mapping and navigation, making movement smooth even in dynamic and intricate environments. One major mechanical enhancement is the incorporation of a metallic arm with a suction device that can remove small and pointy items and store them in a special protective compartment. This function not only maximizes cleaning efficiency but also protects inner parts from damage and enhances user safety in cluttered environments.

The robot will utilize simultaneous localization and mapping (SLAM), with LiDAR and AI-based algorithms to build and update in real time a map of its environment. This allows the robot to precisely establish its location in the environment and make effective navigation decisions. By continuously adjusting to dynamic layouts and obstacles, SLAM provides for seamless and collision-free movement during cleaning sessions.

For further enhanced operational effectiveness, the robot will make use of advanced path planning techniques like A* and Dijkstra's. These algorithms determine the optimal path to clean with and adapt dynamically to new objects sensed or changes in layout. This not only conserves time but also provides complete coverage of areas while optimizing energy consumption. Irrespective of whether the space is static or very dynamic, the robot will plan and navigate the shortest and most effective path.

Deep learning will enable the robot to identify a broad range of objects on the floor, ranging from routine clutter to possibly dangerous substances. Through trained neural networks, the robot can distinguish between obstructions, litter, and objects that are to be picked up or avoided. This ability guarantees context-sensitive cleaning and boosts the robot's responsiveness to real-world household situations.

The inclusion of AI-powered grasping and suction control will enable the robot's metal arm to engage with the environment more cognitively. It will interpret object shape, size, and orientation to calculate the best grip and suction force. This prevents dangerous or sharp objects from being collected in a way that may damage the internal mechanism or the cleaned surface, thus making the robot safer and more effective under unpredictable circumstances.

For thorough cleaning, the robot will employ edge detection and coverage optimization techniques. These AI-driven algorithms will enable the robot to detect the precise boundaries of a room and clean corners and edges to perfection—spaces often neglected by traditional robots. It will adjust its cleaning approach according to floor plan, obstructions, and the structural features of the room to provide a detail-oriented cleaning experience.

In addition to enhancing its cognitive abilities, the robot will also utilize reinforcement learning algorithms, allowing it to learn from experience and adapt its navigation methods with time. With new situations encountered, decision-making will be enhanced through trial and error, steadily optimizing its performance for every distinct environment. This flexibility allows the robot to become more efficient with every

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application, delivering smarter and more tailored cleaning with minimal interference.

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